MEG correlates of grapheme monitoring in picture names

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1 Introduction

Grapheme monitoring is a promising tool to investigate electrophysiological correlates of picture naming, with the possibility (I) to control subjects performance without overt naming and (II) to detect distinct processing stages of picture naming in the event-related magnetic field. In this paradigm, subjects decide whether a target letter is present in the name of an object drawing or not. When they base their decision on a serial "left-to-right" encoding of the picture name, reaction times should be shorter for targets at the beginning than at the end of the picture name ("begin" and "end" condition, respectively) [1]. At the point in time when subjects have detected the target in the "begin" condition, but are still monitoring in the "end" condition, the corresponding evoked responses should diverge. We hypothesize that the time after this "point of divergence" in the end condition reflects the encoding of the picture name.

We applied two experimental tasks: In the "target-picture" (TP) task, the target letter is presented before the picture. Subjects must go through all processing stages of picture naming after picture onset to accomplish this task. In the "picture-target" (PT) task, the target letter is presented after the picture. The PT task was introduced to explore, whether the serial "left-to-right" strategy is specific to the naming process or a general property of our monitoring task, since subjects have sufficient time to retrieve the picture name before the monitoring process starts.

In a previous EEG study, Hauk et al. [2] found a predominantly anterior and left-lateralized brain activity during the encoding of the picture name in the TP task, which we consider as the analogon of the phoneme monitoring task used in [1]. The present study intends to obtain complementary information about the neuronal correlate of picture naming from MEG.

2 Methods

Twelve healthy monolingual native speakers of German participated successfully in this study. Sixty line drawings of objects from the Snodgrass and Vanderwart picture series [3] were chosen, to which some further pictures from our department were added. All object names were monosyllabic and had consonants at their beginning and end. They had a mean word length of 4.15 letters and a mean word frequency of 200.4 (standard deviation 251) per million according to the CELEX data base. Targets in the monitoring tasks were 14 consonants, which should be detected either at the beginning (25% of trials) or at the end (25%) of a picture name, or were not present at all in the picture name (in 50%).

The target consonants were presented visually, either preceding (TP) or following (PT) the picture by 500ms (figure 1). The second stimulus was presented until 300ms after button press.

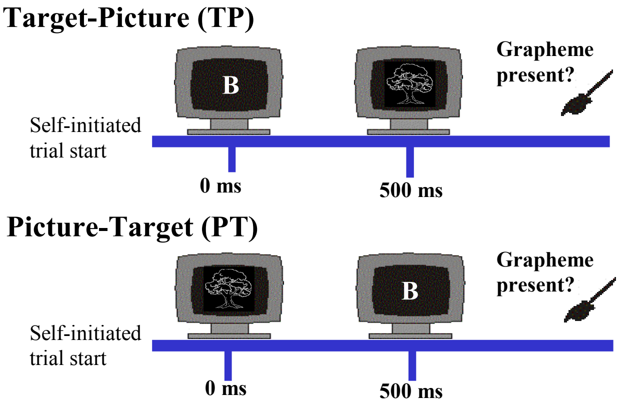

Figure 1: *Schematical demonstration of the grapheme monitoring task.*

Data were recorded with a 148 channel whole head MEG system (BTI Magnes 2500WH) with a sampling rate of 254.3 Hz (online band-pass filter 0.1-50 Hz). Averaging and artefact correction using the procedure suggested by [4] was performed with the Focus Software (Megis Software GmbH, Munich). A 100ms interval preceding the first stimulus was chosen for baseline correction. Grand mean data were computed for visualization. This was accomplished by first computing a minimum norm (MN) solution for the individual data, and then computing the corresponding forward solutions on the average sensor geometry. These were averaged over subjects.

The point of divergence between the “begin” and “end” conditions was determined by 1. computing the difference waves between these conditions for all subjects individually; 2. calculating the root-mean-square (RMS) of the difference waveforms for a selection of 36 left-frontal channels; 3. subtracting the mean RMS across all time points until 100ms after presentation of the second stimulus as baseline correction; and 4. computing paired t-tests against the zero level for each time point across subjects to determine significant variation from zero. The point of divergence was determined as the first of five successive time points (~20ms) later than 100ms after the second stimulus with $p<0.05$.

Topographical analyses concentrated on mean topographies for two time intervals: The first from -150ms to –50ms before the point of divergence, the second from 0ms to 100ms after the point of divergence. MN estimates for these intervals were computed in a spherical head model according to [5], using a 3D source space consisting of four concentric shells with different radii, from which the second uppermost shell was selected for analysis. Regularisation to suppress the influence of noise was applied such that the mean residual variance across data sets was approximately 5%.

For statistical comparisons using ANOVA modeling, dipoles were divided into 9 clusters (left/middle/right and anterior/medial/posterior, medial and posterior clusters) and LATERALITY (i.e. left, central, and right clusters). Hemispheric asymmetry of the MN estimates was examined by the “laterality index” (L-R)/(L+R); L,R: activity summed over the left and right hemisphere, respectively); changes between anterior and posterior brain regions were analyzed correspondingly by the “gradient index” (A-P)/(A+P). respectively). The ANOVA model contained the repeated measures factors GRADIENT (i.e. anterior,

3 Results

Reaction times were analyzed within an ANOVA model including the within subjects factors TASK (TP and PT) and CONDITION (“begin” and “end”). Both main effects were significant (TASK: F(1,11) = 78.6, $p<0.001$; CONDITION: F(2,22) = 54.7, $p<0.001$). Post-hoc Scheffé-tests revealed that subjects responded faster in the “begin” compared to the “end” conditions (TP “begin”: 867ms, “end”: 1020ms; PT “begin”: 668ms, “end”: 839ms; $p<0.001$).

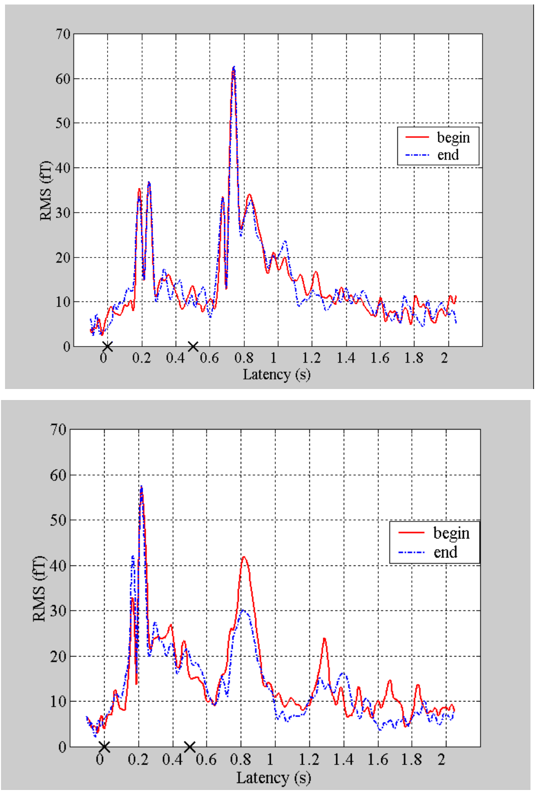

Figure 2**:** *Root-mean-squares over time for “begin” and “end” conditions in the Target-Picture (top) and Picture-Target (bottom) task. The crosses indicate the onsets of the first and second stimulus (letter or picture), respectively.*

The difference was 153ms for the TP task and 171ms for the PT task. Subjects were faster by 187ms in the PT task compared to the TP task. To test whether these differences are due to the same strategies used by the subjects in both tasks, we correlated differences between “begin” and “end” conditions of TP and PT tasks over subjects. This correlation was significant ($r=0.72$, $p<0.01$), in contrast to the results of the EEG experiment. The points of divergence were found at 453ms after picture onset for the TP task, and 331ms after target onset for the PT task (EEG study: 465ms and 320ms, respectively). The p-value curves are shown in figure 3, the corresponding RMS curves for “begin” and “end” conditions in figure 2.

A 4-way ANOVA for minimum norm estimates including the repeated measures factors TIME, CONDITION, GRADIENT and LATERALITY revealed significant TIME by GRADIENT interactions for both tasks (TP: F(2,22)=10.0, $p<0.01$; PT: F(2,22)=14.7, $p<0.001$). Grand mean topographies and corresponding minimum norm estimates for mean time intervals before and after the point of divergence are shown in figure 4.

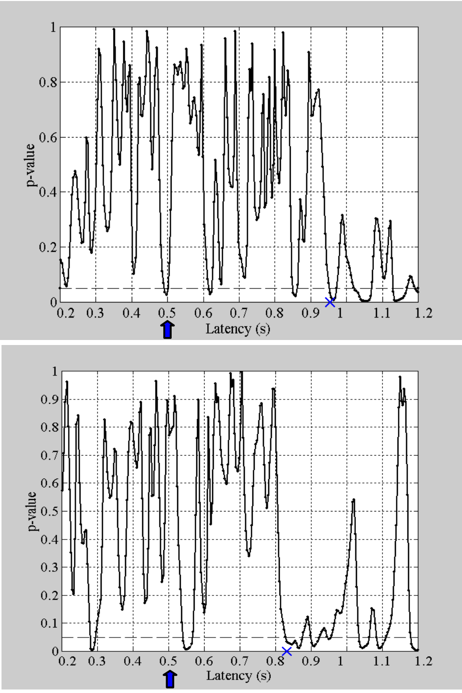

Figure 3: *The p-value curves for "end" minus "begin" in the TP (top) and the PT (bottom) tasks. The crosses mark the points of divergence, the arrows mark the onset of the second stimulus. The dashed line indicates the $p=0.05$ level.*

The lateralization indices for both tasks revealed main effects for CONDITION ($F(1,11)=5.3$, $p<0.05$) and TIME ($F(1,11)=6.3$, $p<0.05$), but in contrast to the EEG study no significant interactions. The gradient indices showed significant main effects for CONDITION and TIME ($F(1,11)=39.3$, $p<0.001$; $F(1,11)=32,4$, $p<0.001$, respectively) as well as a ($F(1,11)=22.8$, $p<0.001$), which is mainly caused by the higher gradient after the point of divergence in the "end" conditions ($p<0.001$). The lateralization and gradient indices are presented for individual subjects in figures 6 and 7.

4 Discussion

The dependence of reaction times on the position of the target letter in the picture name and the divergence of the ERP waveforms indicates a serial "left-to-right" processing of a representation of the picture name, which is in line with the results of [1]. Contrary to our EEG study [2], behavioral and electrophysiological findings do not suggest different processes for TP and PT tasks.

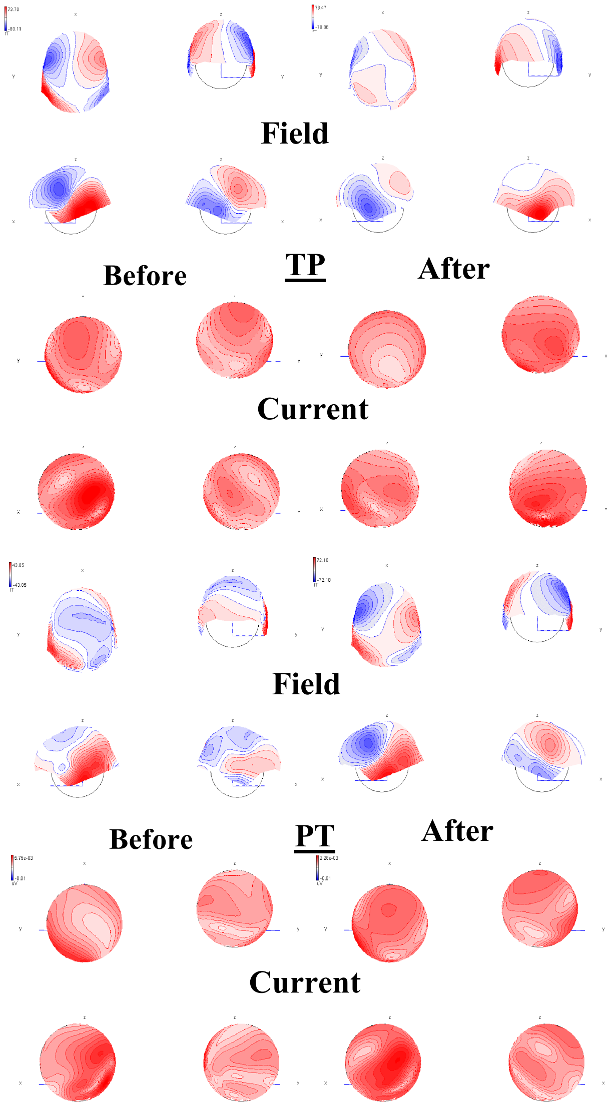

Figure 4: *Grand mean magnetic field topographies and minimum norm current densities of the TP and PT tasks for time intervals before and after the point of divergence. Views are from top, front, right and left (clockwise).*

The left-lateralized frontal activity, which was present in the EEG data, could not be detected in the MEG study. A possible reason is the high degree of topographical variability over subjects. MEG exhibits a higher contrast with respect to orientation and depth of sources than the EEG. For the MEG, the contribution of radial sources compared to tangential ones is small, and deeper sources contribute much less than superficial ones. This can either result in higher variability over subjects, or in decreased effects.

However, as in our EEG study, an increase of activity in frontal regions after the point of divergence was found, which differed between “begin” and “end” conditions. This shift of brain activity from posterior to anterior in the course of speech production is also in accordance with results from [6] and [7].

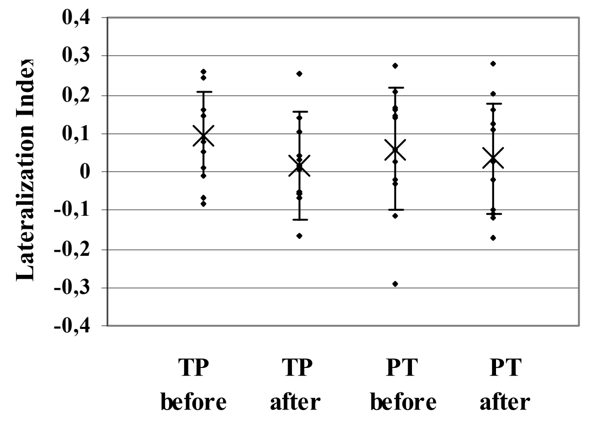

Figure 5: *Lateralization indices (L-R)/(L+R) for individual subjects in the “end” condition of TP and PT task for mean latency ranges before and after the point of divergence. Crosses represent the mean across subjects, and are shown with their standard deviations.*

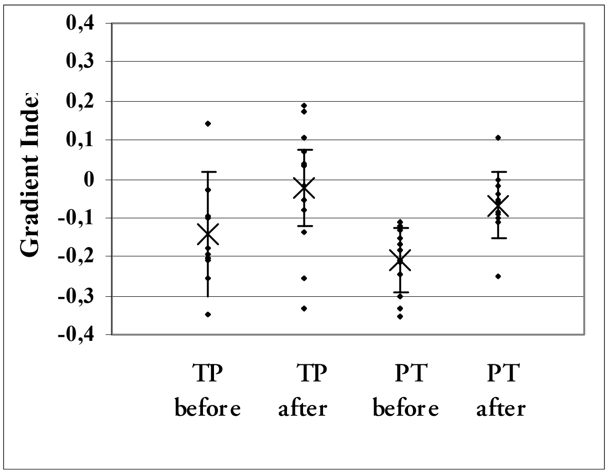

Figure 6: *Gradient indices (A-P)/(A+P) for individual subjects in the “end” condition of TP and PT task for mean latency ranges before and after the point of divergence. Crosses represent the mean across subjects, and are shown with their standard deviations.*

Acknowledgements

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